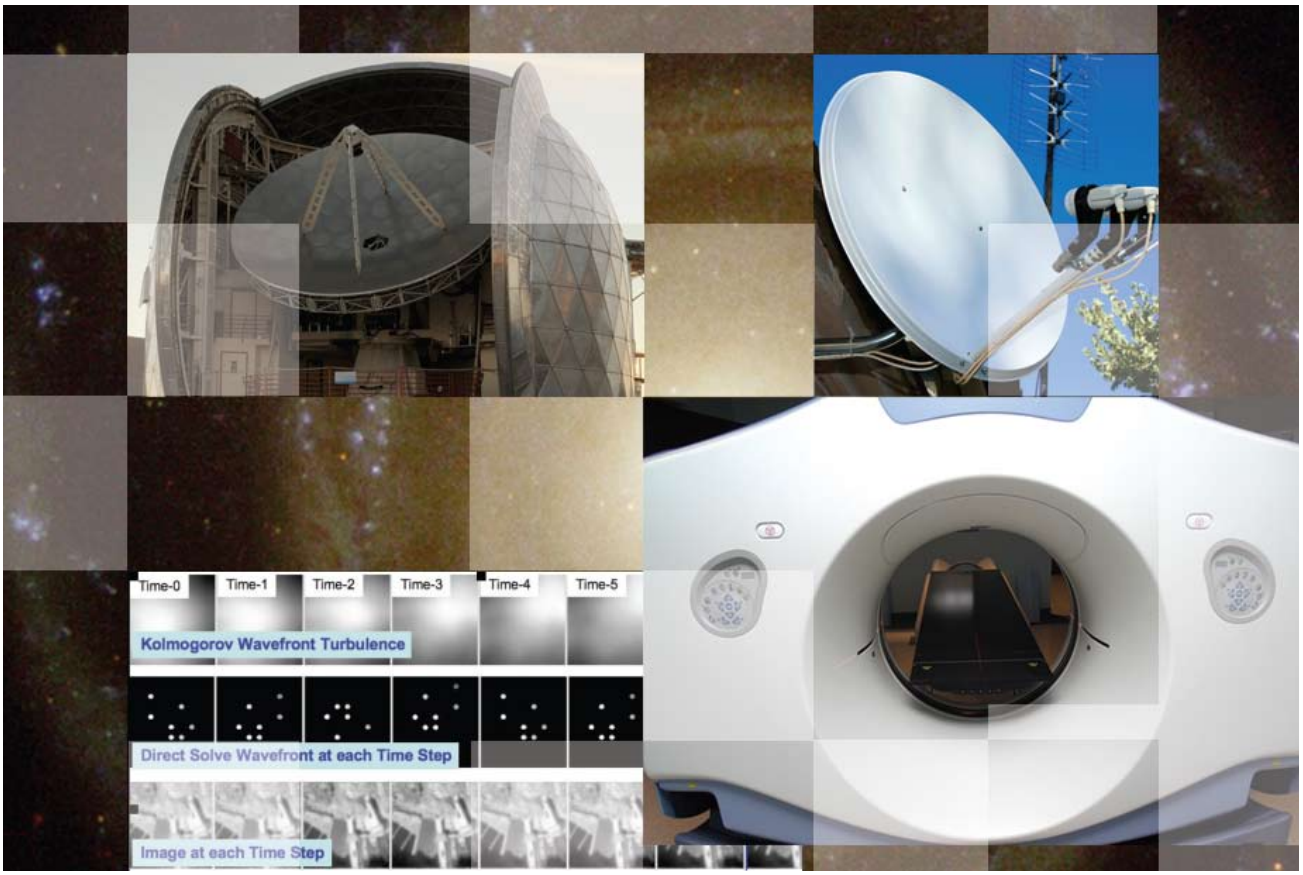
National Aeronautics and Space Administration

technology opportunity

Direct-Solve Image-Based Wavefront Sensing

A direct, robust, and fast approach to wavefront sensing and control



NASA Goddard Space Flight Center (GSFC) invites companies to license a revolutionary new method for image-based wavefront sensing. This approach directly solves for wavefront errors using only a single broadband in-focus image as input. No nonlinear, iterative algorithms (e.g., phase retrieval) are required. The single image is fed to a software algorithm, which directly solves for the wavefront in a fraction of a second on a single-processor computer. This technique is designed for speed and can be used in any open- or closed-loop control system.

Benefits

- **Fast**: Produces results in ~0.01 seconds on a single processor computer
- **Simple**: Requires no additional hardware, no interpretation of results, and no experienced interferometer engineer
- **Robust**: Always reaches a solution in a fixed number of floating point operations, without any iteration
- **Broadband**: Uses all available light (photons) and no narrowband filters are required

Applications

This technology is applicable in any environment requiring high-speed acquisition of the wavefront in either open- or closed-loop (i.e., with feedback to a control system to correct the wavefront and hence image quality) systems. Some systems that could benefit are:

- Ground-based telescope and interferometer systems
- Space-based telescope and interferometer systems
- Antennas and antenna arrays
- Microwave systems
- Medical imaging systems, such as MRI

Technology Details

Wavefront sensing is used in the manufacture and testing of optical components, telescopes, microscopes, cameras, and other optical systems. In addition, it is frequently used in microwave and radio imaging systems.

Wavefront errors are used as a diagnostic to assess optical and/or imaging performance during the build phase of an optical system, during *in situ* operations for closed-loop systems of an active or adaptive optical system, or during both. Diagnosis allows for a feedback loop to correct, or control, these errors – resulting in a corrected image.

Standard approaches for acquiring wavefronts use complex lab interferometers and/or Shack-Hartmann sensors, which suffer from errors due to non-common paths and are costly and complex instruments. While phase retrieval approaches generally do not suffer from non-common path errors, they do typically require multiple images and inherently non-linear iterative algorithms. Both approaches require trained engineers or experts in phase retrieval to interpret results.

How it works:

In standard approaches, such as interferometers, phase retrieval, and Shack-Hartmann sensors, the wavefront is first decomposed into a set of specialized nonlinear patterns and each pattern is subsequently decomposed into a set of localized regions—the sample points. The local wavefront errors per pattern are directly recovered and combined to sense the entire wavefront. This works due to the broadband nature of light containing more information (in a rigorous sense) than monochromatic or narrowband light.

This new direct-solve algorithm uses only a single image at each step and does not require iterative algorithms. This is in contrast to conventional phase retrieval approaches, which require multiple iterations and/or multiple input images. The method requires only the instrument under test (or to be controlled), the internal focal plane (which must already exist as part of the instrument), an interface to the camera (or other imaging device), and the direct-solve software that solves for and then either displays or parameterizes the recovered wavefront.

Why it is better:

The algorithm is fast, very stable, robust, and always reaches a solution in a fixed number of floating point operations, executing in ~0.01 seconds on a single-processor computer. There are no sign ambiguities, phase unwrapping, or convergence issues. This method will ultimately save personnel time, computer time, and will result in a net cost saving. It lends itself well to both open- and closed-loop operations.

Patents

NASA Goddard Space Flight Center is seeking patent protection for this technology.

Licensing and Partnering Opportunities:

This technology is part of NASA's Innovative Partnerships Program, which seeks to transfer technology into and out of NASA to benefit the space program and U.S. industry. NASA invites companies to consider licensing the Direct-Solve Image-Based Wavefront Sensing (GSC-15208-1) for commercial applications.

For More Information

If you are interested in more information or want to pursue transfer of this technology (GSC-15208-1), please contact:

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